A.S.E. Source at 1550nm for IFOG Applications

Annual Progress Report

Period: 9/5/97 to 9/5/98

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To whom it may concern,

Enclosed is a copy of the annual progress report for the A.S.E. Source at 1550nm for IFOG Applications contract.

Sincerely,

Ben Ellerbusch

Benjamin Ellerbusch

Benjamin P. Ellerbusch
Graduate Student

BPE

Enclosed: 1 copy

Project Title: A.S.E. Source at 1550nm for IFOG Applications

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Results

Work has progressed in the following areas for the designing and characterization of the A.S.E. source at 1550nm for IFOG applications:

1. Luminescence measurements have been performed on samples of all doping levels and show little variation in spectrum between samples. All doping levels exhibit smoothly varying, broadband luminescence with a width around 50nm.

2. The addition of Lanthanum as a codopant yielded little or no improvement in luminescence spectrum or luminescence lifetime. Samples with Lanthanum codoping yielded spectra that were less uniform, but similar in width with no increase in output power. Luminescence lifetimes of Lathanum codoped samples both increased and decreased from sample to sample. Accordingly, no more runs are expected to be performed using Lanthanum as a codopant.

3. Scattering loss measurements have been done using the cut-back method and yield in-guide losses ranging from 0.9dB/cm to 1.2dB/cm at the 980nm and 1550nm wavelengths. A new guide structure with lower index differences between the guiding and cladding layers has been proposed and is now being fabricated in an effort to reduce these scattering losses. Undoped waveguides with these new indices will soon be ready for loss measurements.

4. The new waveguide structure has been designed with reduced index differences between the cladding and guiding layers to reduce scattering losses, and an increased guiding layer thickness to improve the shape of the mode within the waveguide. This structure consists of three Alumina layers and is pictured schematically in Figure 1.

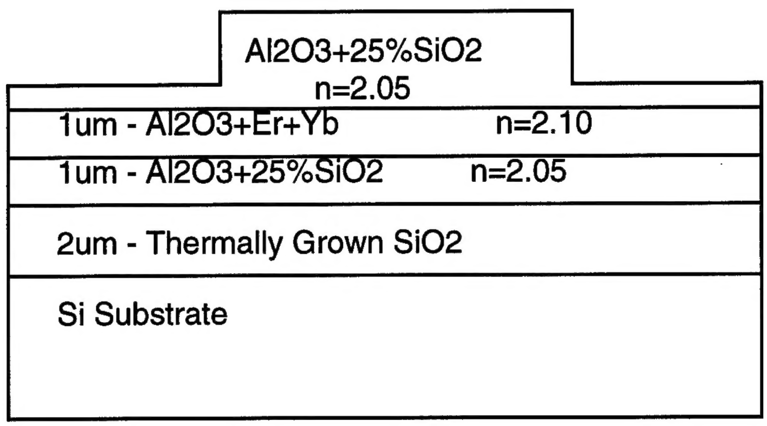

Figure 1: All-Alumina, Lower Index Difference, Ridge Waveguide Structure

The index difference between layers has been reduced from being greater than 0.1 to being about 0.05. The doped, guiding layer thickness has been increased from 0.5um to 1.0um in order to both improve the shape of the mode within the waveguide and increase ASE output power.

5. High losses for fiber-to-facet and lens-to-facet coupling allow us to launch only 30-40mW of pump power into a single-mode waveguide. Coupling losses for single-mode fiber-to-facet coupling are around 10dB while coupling losses for the lens-to-facet coupling are 6-8dB. Several steps are being taken to minimize these losses including the use of specialty lenses for free space coupling, using tapered fiber for fiber coupling, and coupling into tapered waveguides.

6. Relative gain measurements have been performed by measuring the increase in signal amplitude with increasing pump power. Results of these measurements show that the 0.1%Er-0.2%Yb codoped samples possess the highest gain of ~1.2dB/cm. Absolute, in-guide gain estimates will be obtained when coupling losses have been reduced and are more accurately known.

7. Luminescence lifetime measurements have been performed on samples of all doping levels with bake temperatures ranging from 400-800 degrees C. The longest lifetime measured in the old, high index difference, SiO_2/Al_2O_3 structures was 4.3ms for the 0.05%Er doped sample baked at 500 degrees C for one hour. Recent lifetime measurements in the new all-Alumina structures yield a lifetime of 5.5ms for a sample doped with 0.05%Er-0.2%Yb and baked at 500 degrees C for two hours. Measurements will be performed on other doping levels, but this is a very promising result.

8. The 1.53um ASE output power has been measured for the Al_2O_3/SiO_2 structures for all doping levels. ASE output power is affected only slightly by increasing Erbium doping level, but the addition of Ytterbium codoping increases the ASE power by a factor 5-7 times. 5cm long waveguides with no Ytterbium codoping yielded ASE output powers ranging from 1 to 3uW while those with Ytterbium as a codopant yielded ASE output powers of 10-15uW. These codoped guides have a very short lifetime of about 0.5ms, but recent lifetime measurements of 5.5ms with the new structure codoped with Ytterbium show that this result can be greatly improved upon.

9. Two waveguide amplifier samples 4cm in length were optically coated with dichroic coatings in order to create 1.53um lasers. These samples were coated as follows: ~100% reflectivity for 1.5um at the input facet, anti-reflection coated for 980nm at the input facet, 50-

70% reflectivity for 1.5um at the output facet, and ~100% reflectivity for 980nm at the output facet. The coated waveguides used the old structure and were doped with 0.1%Erbium with no Ytterbium codoping. The samples did not lase and showed output powers similar to those of the uncoated waveguides (~3uW). Two more samples have been sent for coatings using the higher gain Er/Yb codoped samples. These laser samples should soon be ready for testing and, if found to lase, can be used to more accurately determine both gain and loss for the waveguides.

Ongoing Work

1. Waveguides are being etched in the new Alumina structures and they will soon be ready for scattering and coupling loss measurements. The doping levels for these structures have been chosen with varying Er/Yb concentrations and ratios in an effort to determine the optimum doping level for maximum ASE power output.

2. Experimentation continues with the design, fabrication, and coupling of tapered fibers being done in-house. Initial etches reveal excellent tapers, but Hydrogen flaming has produced poor lenses.

3. Free space coupling continues to be the most efficient way to couple pump power into the waveguides. A purchase order has been submitted for an objective lens designed for coupling 980nm and 1550nm sources into waveguides and fiber. This lens is anti-reflection coated for the near infra-red, infinity corrected for focusing laser sources, and is designed to have a constant focal length for the 900-1500nm wavelength range. This lens should decrease our coupling losses by a couple dB and allow us to couple more power both into and out of our waveguides. This lens, coupled with the new, thicker, waveguide structure should result in higher gain and much higher ASE output power.

4. Work is being done on designing low loss waveguide tapers which would be used to gradually reduce the focused laser mode size down to a size that would match that of our waveguide, thus further reducing coupling losses and increasing pump power launched into the waveguide. This taper design will soon be ready for fabrication and testing. With the addition of the new lens, tapered fibers, and tapered waveguides, coupling losses should be decreased to around 3dB allowing for much more pump power to be launched into the waveguides.

5. Calculations are being done to determine losses in waveguide bends using the new all-Alumina structure. With these loss calculations and decreased coupling losses, >20cm long, curved waveguides will be designed to increase the net gain and greatly increase the ASE output power of the 1550nm light source.

Conclusion

Work has progressed in the testing and characterization of Erbium and Ytterbium doped waveguides. Areas for improvement have been identified and include reducing waveguide and coupling losses as well as increasing ASE output power and gain. Several steps, including a new waveguide structure, have been taken to improve performance in each of these areas and initial lifetime measurements done with the new guide structure show that work is progressing in the right direction.